U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 99.

B. T. GALLOWAY, *Chief of Bureau.*

A QUICK METHOD FOR THE DETERMINATION OF MOISTURE IN GRAIN.

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99
2

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., November 3, 1906.

Sir: I have the honor to transmit herewith a manuscript entitled "A Quick Method for the Determination of Moisture in Grain," and to recommend that it be published as Bulletin No. 99 of the series of this Bureau.

By means of the method and apparatus described it is possible to make complete moisture determinations of grain in from 20 to 25 minutes. This makes it practicable in commercial work to include a definite statement of the moisture content among the factors determining quality.

This paper was prepared by Mr. Edgar Brown, botanist in charge of the Seed Laboratory, and Dr. J. W. T. Duvel, assistant in the Seed Laboratory. The illustrations which accompany it are necessary to a full understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

99

ILLUSTRATIONS.

99

B. P. I.—240.

A QUICK METHOD FOR THE DETERMINATION OF MOISTURE IN GRAIN.[a]

QUALITY OF EXPORT CORN.

During the past few years the commercial grading of corn has been a matter of much controversy, both in the United States and in Europe. Complaints of the poor condition of corn on arrival at European ports have been constantly increasing, corn inspected at American ports as No. 2, or "prime sail," having proved in many cases unfit for feeding purposes when discharged at foreign ports. This uncertainty as to quality has already led European buyers to purchase largely from other corn-growing countries, and unless the quality of corn exported from the United States is improved our foreign trade must inevitably suffer. Last year the total quantity of corn imported into France (general trade) was, in round numbers, twelve and three-fourths million bushels, of which the United States furnished only 20.9 per cent, or approximately two and two-thirds million bushels, while Argentina alone supplied 64.4 per cent, or approximately eight and one-fourth million bushels.

CAUSES OF DETERIORATION.

The principal cause of the deterioration of corn during transit or in storage is an excessive amount of moisture. Corn as it is harvested in the autumn ordinarily contains from 20 per cent to 35 per cent of water, depending on the season and the relative time of harvesting. Much of the corn as it comes from the fields goes directly into the small elevators thruout the corn-growing States, to be transferred later to the large elevators or storage bins at the grain centers. Owing to the cold weather usually prevalent at this season of the year, corn may be stored or exported without much danger of deterioration, even tho the water content is relatively high, but with a slight rise in temperature it will begin to sweat, after which fermentation soon sets in, resulting in moldy and damaged grain.

[a] Application has been made for a patent on the apparatus described in this bulletin, in order that it may be used or manufactured by any person in the United States without the payment of royalty.

With the present system of grain inspection, when hundreds of cars must be inspected daily, and the water content of the corn is determined only by feeling the corn with the hand or by biting the kernels, any degree of accuracy is next to impossible. Most of this work is done in the cars on the track and sometimes when the mercury has gone below the zero mark.

THE PERCENTAGE BASIS FOR MOISTURE DETERMINATIONS.

There seems to be a growing demand among grain men and inspection departments for a more definite and uniform system of grading, which is taking the form of an agitation for uniform rules for grades. Any system of uniform grading to be effective must be based on a percentage statement of the various factors which go to make up the quality and condition of any particular lot of grain in order to insure uniformity of application. With this in view, a considerable amount of preliminary work has been done for several years in the Bureau of Plant Industry, which will later aid in formulating rules to place the grading of grain on a basis which will permit stating the elements of condition and quality in definite terms.

Members of boards of trade and chambers of commerce, as well as most grain inspectors, have been much in doubt as to the practicability of incorporating in their rules a percentage statement of moisture in grain, and with the methods commonly employed for making moisture determinations the percentage system is not suitable to the present condition of the grain trade, save, perhaps, in a few special cases. Heretofore the minimum time required to make a moisture determination of a sample of grain was from six to eight hours, and this was accomplished by drying a carefully weighed ground sample in a glycerin oven or in a vacuum at a temperature of 105° or 108° C. If the drying be done in an ordinary water oven, such as is commonly used, the time must be extended to from sixteen to twenty hours. To each of these periods must be added the time occupied in grinding and weighing the sample preparatory to drying, and likewise the time required for the samples to cool in the desiccator before the final weighing. If whole kernels are used instead of a ground sample, the time required by the process at present in use must be extended to from sixty to ninety-six hours.

But, disregarding the time factor, the method outlined is not applicable to commercial corn containing a relatively large percentage of water. Practically all of the machines available for grinding samples of grain for analysis are of the "burr" type, and during the grinding the temperature of the grain is increased to such an extent that from 0.5 per cent to 1.5 per cent of moisture is lost in the process of grinding, unless the corn has been well cured and dried, in which case a moisture determination is not needed.

It has therefore become necessary to devise some suitable method and apparatus for determining the amount of water in corn and other grains before any hope of placing the grading of grain on a percentage basis can be entertained seriously at any of our large grain centers. It is hoped that the method described in the following pages, which is applicable to the testing of wheat and other grains as well as corn, will be sufficiently rapid and easy to make it of practical value to the grain trade, and possibly to other industries.

DESCRIPTION OF A METHOD FOR THE RAPID DETERMINATION OF MOISTURE.

The fundamental principle[a] on which this method of moisture determination is based consists in heating whole grains in oil to a temperature considerably above that of boiling water and thus driving out the water, which is afterwards condensed and measured in a graduated flask. With this method it is possible to determine the percentage of water in a sample of corn in from twenty to twenty-five minutes.

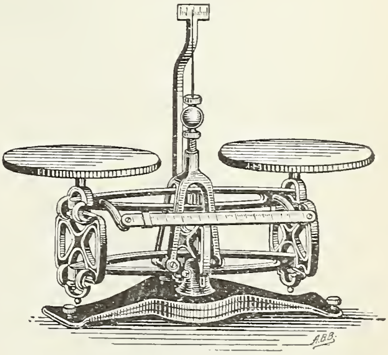

FIG. 1.—Balance for weighing grain samples.

One hundred cubic centimeters of a good grade of hydrocarbon oil are measured and poured into a glass distillation flask (see fig. 10). One hundred grams of corn are weighed on a torsion balance similar to the one shown in figure 1, the corn being emptied at once into the flask containing the oil. The neck of the flask is closed with a good rubber stopper carrying a thermometer, the bulb of which should extend well into the mixture of oil and corn. The side of the flask is then connected with a condenser by means of a second rubber stopper. With a strong gas burner the corn in the oil bath is then heated until the thermometer registers 190° C. (374° F.), at which time the flame is extinguished. The time required for the temperature to reach 190° C. will be from ten to fifteen minutes, depending on the amount of water in the corn and on the volume of the flame. Eight or ten minutes after the flame has

[a] This principle has already been described by Dr. J. F. Hoffmann in Zeitschrift für Angewandte Chemie, Berlin, 1902, p. 1193, and in the Grain Dealers' Journal, Chicago, May, 1906, p. 526. However, the apparatus used by Hoffmann and likewise the details of the method described by him have proved unsuitable where large numbers of samples are to be analyzed. Consequently, in August, 1905, experiments were begun to simplify the Hoffmann method and to devise an apparatus which would prove practical for laboratories handling a large number of samples of grain.

been removed the water will have ceased dropping from the condenser, and the number of cubic centimeters of water contained in the graduated cylinder beneath the condenser tube can be ascertained. This is the water actually removed from the corn and represents the percentage of moisture originally in the sample, each cubic centimeter of water representing 1 per cent when a 100-gram sample is used. By the use of this method, together with the special apparatus described in this bulletin, a person familiar with laboratory work and an assistant should be able to make at least 200 moisture determinations in a day of eight hours.

PREPARATION OF SAMPLES FOR MOISTURE DETERMINATION.

TAKING THE BULK SAMPLE.

Care in drawing the bulk sample from the car, cargo, conveyer, etc., is of the utmost importance and can not be too strongly emphasized, for unless this part of the work is properly done the true percentage of moisture in the grain can not be determined.

The samples should be taken in such a way as to represent as nearly as possible the condition of the entire lot of grain under consideration, and in this respect the method herein described does not differ from any other system of inspection. The number of samples to be drawn from different parts of the bulk will depend upon the quantity and quality of the grain to be past upon. The larger samples so drawn may be analyzed separately or they may be mixt together to form one composite sample representing the entire bulk and the smaller samples for the individual moisture determinations taken from this mixture, as the conditions may warrant. If the bulk of corn being examined is of uniform quality, a moisture determination of the composite sample will suffice; but if the bulk lacks uniformity, and particularly if of a low grade, the samples taken from different parts of the grain under consideration or at different times during the "running" should be analyzed separately. At the same time the amount of grain represented by each sample should be estimated. But whatever samples are intended for moisture determination must be put at once into a suitable air-tight container in order to prevent any drying of the grain on being exposed to the air; otherwise the amount of moisture actually present can not be accurately determined. This precaution is particularly important in the case of samples drawn from any bulk lot of grain which has begun to sweat.

TAKING THE SAMPLE FOR THE MOISTURE TEST.

The accuracy of any method of determining moisture depends primarily on the small sample used for the test being thoroly repre-

sentative of the bulk sample. In order that the small sample may be representative, the bulk sample should be thoroly mixt and small portions taken from different parts of it. The greatest accuracy can be secured thru the use of some form of mechanical mixer and sampler, and the one shown on pages 12 and 13 of Circular 34, Revised, Office of Experiment Stations, modified so as to be adapted for larger grain, is recommended.

SIZE OF SAMPLE FOR THE MOISTURE TEST.

The size of the sample to be taken for the individual moisture test may be varied, but experience has shown that 100 grams of whole kernels give the most satisfactory results, which quantity has therefore been established as the standard for the method and apparatus for testing corn herein described. This is a sufficiently large quantity to insure the securing, without difficulty, of a representative sample. Moreover, when samples containing 100 grams are used, every cubic centimeter of water expelled from the grain represents 1 per cent of moisture, and the readings in the graduated cylinders are in percentages as well as in volume, thereby reducing the chances of error to a minimum.

WEIGHING THE SAMPLE FOR THE MOISTURE TEST.

In making moisture determinations according to the method outlined in the foregoing pages, the use of delicate analytical balances is obviated. An ordinary torsion balance similar to the one shown as figure 1, which is sensitive to one-thirtieth of a gram and can be purchased for about $15, will serve every purpose. A more delicate balance is entirely unnecessary when it is remembered that one kernel of corn weighs approximately one-third of a gram. The scale pans are 6 inches in diameter, and the side beam shows 5 grams, graduated in one hundred divisions, each one-twentieth of a gram, and the total capacity of the balances is 2 pounds, or 907 grams. Balances of this kind are easily operated, and the time consumed in the weighing need not be longer than that required for the pharmacist to weigh out the prepared drugs for his medicines.

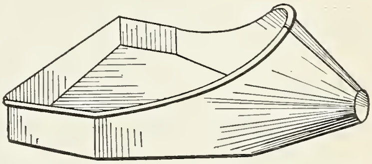

FIG. 2.—Aluminum weighing pan for transferring grain samples to the distillation flasks.

A specially constructed scale pan, such as is shown as figure 2, should be secured to facilitate the transferring of the weighed samples to the distillation flasks, the opening in the end of the scoop being of the same size as the neck of the flasks—1 inch. If made of

light material, preferably aluminum, a scoop of this kind need not weigh more than 50 or 75 grams and can be substituted for one of the scale pans or used with a counterpoise. The scoop should be about 4 inches wide.

GRINDING THE GRAIN UNNECESSARY.

The whole kernels are used for making the moisture determination, thus doing away with the preliminary grinding of the samples; in fact, the method described is not applicable, without some modification, to samples of ground grain. Ground samples have a tendency to cake in the bottom of the flask and prevent a free circulation of the oil, with a corresponding variation in the temperature at different points in the sample of meal, and the results obtained are not reliable. Moreover, the grinding of samples for the determination of moisture in commercial grain is always to be avoided. Grain of this character generally contains a high percentage of moisture, and with the "burr" type of mill usually used for grinding samples of this kind the friction developed during the grinding causes a rise in temperature and a corresponding loss of moisture. This loss of moisture increases as the water content of the grain increases, and in samples of grain which have begun to sweat this loss is frequently as much as $1\frac{1}{2}$ per cent.

OIL FOR THE MOISTURE TEST.

QUALITY REQUIRED.

In securing an oil suitable for the bath in which the corn is to be heated, five primary factors must be taken into consideration:

(1) The oil must be free from water.

(2) It must be an oil having a comparatively low viscosity, so that it will run freely at ordinary room temperature.

(3) The flash point must be sufficiently high to avoid danger of an explosion or fire.

(4) The saponification value should be zero.

(5) The oil must be cheap.

Experiments have demonstrated that any of the pure hydrocarbon oils showing a composition within the range of the two samples indicated below will give satisfactory results:

	No. 1.	No. 2.
Specific gravity at 15.5° C.	0.9095	0.8957
Viscosity at 20° C. (Engler)	19.2	6.2
Flash point (open cup) degrees centigrade	205	175
Fire point (open cup) do	245	210
Saponification value	None.	None.

An oil similar to sample No. 1 is to be preferred to sample No. 2, owing to the difference in the flash point, altho the latter may be

used with safety if the necessary precautions are taken to prevent the temperature running too high; however, an oil with a flash point as low as 175° C. in an open cup is not to be recommended for general use. An oil with a flash point of from 200° to 205° C. (open cup) and a viscosity of 10 or 15 at 20° C. (Engler) is more desirable. Oils of this character are found among many grades of lubricating oils, especially those known as "engine oils," and can be purchased in barrel lots for about 12½ or 15 cents a gallon.

As the moisture is liberated from the grain the foaming of the oil will be quite pronounced, and the flask must be sufficiently large to prevent the foaming oil from being carried over into the condenser tube. The foaming can be greatly reduced by the addition of from 15 to 20 per cent of paraffin, but this is usually unnecessary.

QUANTITY REQUIRED.

The quantity of the oil in the distillation flask admits of a wide variation, it being only necessary to have such a quantity of oil that all of the grain used for the test will be immersed. One hundred grams of corn require approximately 100 cubic centimeters of oil, while if only 50 grams of grain are used the quantity of oil can be reduced. The quantity of oil used, however, is not an important factor, inasmuch as the greater part of it can be recovered by emptying the contents of the flask into a colander at the close of the test and allowing the oil to drain off. The oil so recovered can be used again with equally as good results as with fresh oil. But even if the oil is not used a second time, 1 gallon, costing 12½ or 15 cents, is sufficient for forty tests.

DESCRIPTION OF THE APPARATUS.

In devising the apparatus for making moisture determinations in accordance with the method outlined in these pages, the principal aim has been to secure an apparatus suitable for laboratories engaged in determining the percentage of water in samples of commercial grain. The following description and the accompanying illustrations (figs. 3, 4, 5, 6, 7, and 8) show the detailed construction of the apparatus.

THE EVAPORATING CHAMBER.

For the want of a better term the name "evaporating chamber" has been applied to that part of the apparatus in which the samples of corn immersed in the oil are heated. (See figs. 4 and 5.) The evaporating chamber (*B*) is made of a good quality of galvanized iron and is divided into six compartments, as shown in figure 4.

A six-compartment chamber is here described, it being the best for ordinary work; however, the apparatus can be made with a single compartment or with a dozen or more, if so desired. Each of the compartments is lined thruout with heavy asbestos. In addition

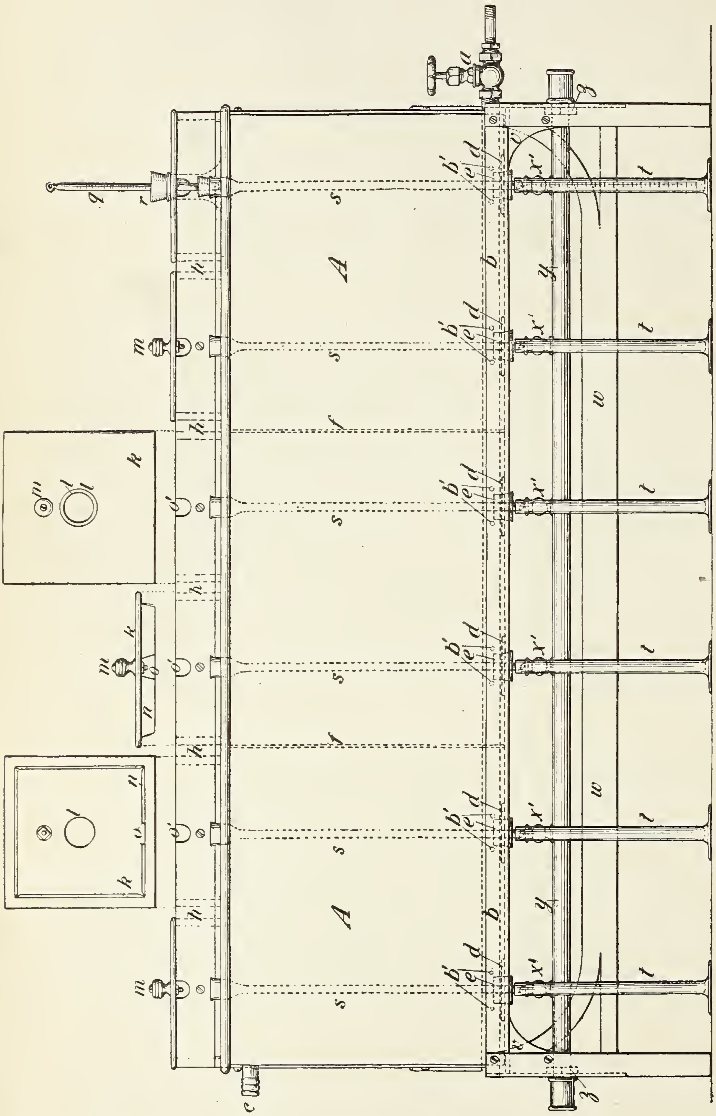

FIG. 3.—Plan of front of apparatus for moisture determination.

A, condenser; *a*, valve on cold-water pipe; *b*, water pipe along bottom of tank; *b'*, diagonal holes in pipe opening into tank; *c*, overflow pipe; *d*, heavy washers; *e*, rubber stoppers supporting condenser tubes; *f*, braces on sides of tank; *h*, air space between compartment partitions in evaporating chamber; *k*, covers; *l*, hole in cover for neck of flask; *m*, wooden handle on cover; *n*, flange on cover; *o*, notch in flange; *o'*, notch in front of evaporating chamber; *q*, thermometer in flask; *r*, rubber stopper supporting thermometer; *s*, glass condenser tubes; *t*, graduated measuring cylinders; *v*, braces on stand; *w*, cross piece on back of stand; *x'*, extra stopcock at base of burner; *y*, gas pipe; *z*, nuts for adjusting height of gas pipe.

to the asbestos lining the front of the chamber—the wall next to the condenser—is covered with heavy asbestos on the outside.

The front of the evaporating chamber and the two ends (figs. 4 and 5) rest on an iron stand (*C*), while the wall at the back of the

chamber extends only to the line *u u'*, which is 5 inches above the base. (See fig. 4.) This side is left partially open to facilitate the lighting of the burners and to give a better supply of air. A 2-inch

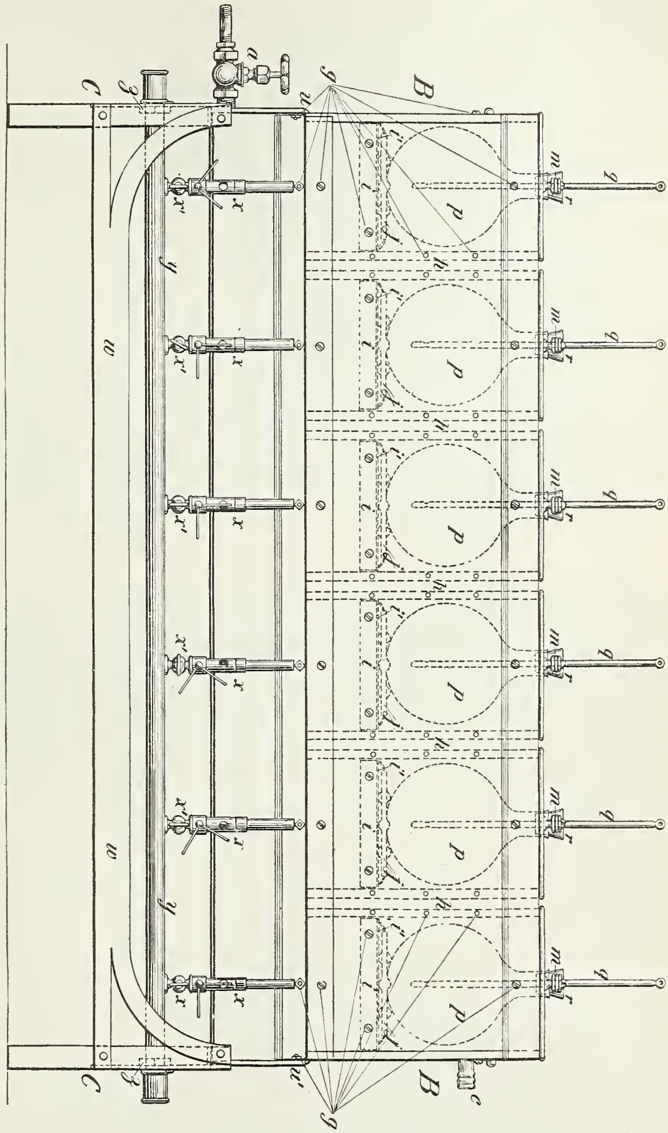

Fig. 4.—Plan of back of apparatus for moisture determination.

B, evaporating chamber; *C*, stand supporting evaporating chamber and condenser; *a*, valve on water pipe; *c*, overflow pipe; *g*, screw bolts; *h*, air space between partitions; *i*, ledge supporting gauze, triangle, and flasks; *i'*, galvanized iron ring above wire gauze; *j*, flanged pipestem triangle; *m*, wooden handle on covers; *p*, distillation flasks; *q*, thermometers in flasks; *r*, rubber stopper carrying thermometers; *u u'*, lower line of outside wall of evaporating chamber; *w*, cross-piece on back of stand; *x*, burners; *x'*, extra stopcock beneath burners; *y*, gas pipe; *z*, nuts for adjusting gas pipe.

hole should likewise be cut in each end of the apparatus about $4\frac{1}{2}$ inches from the base, in order to give a greater supply of air to the two end burners; this, however, is not shown in the illustrations.

The different parts of the evaporating chamber, including the

asbestos lining and covering, are fastened together with the screw bolts (figs. 4 and 5, *g*). The different compartments are each made $5\frac{3}{8}$ inches square inside, and are separated from each other by two partitions, each with a double thickness of asbestos, and a quarter-inch air space (*h*), so that when the heat is turned off from one compartment the sample of corn in the flask within will in no way be affected by the heat from an adjoining compartment should it still be in operation. These partitions extend $2\frac{1}{2}$ inches below the ledges (*i*) which support the flasks (*p*), in order to prevent the flame of any one burner from spreading into an adjoining compartment. Within each compartment, $6\frac{1}{2}$ inches from the top of the chamber, is a galvanized-iron ledge (*i*) for supporting the wire gauze, flask, etc., the ledge being cut in such a way as to form a hole $4\frac{1}{2}$ inches in diameter. In order to prevent the brass-wire gauze from becoming badly distorted by the action of the heat, it should be held in place by means of a second piece of galvanized iron (*i'*), which fits into the compartment and has a hole of the same diameter as the support (*i*).

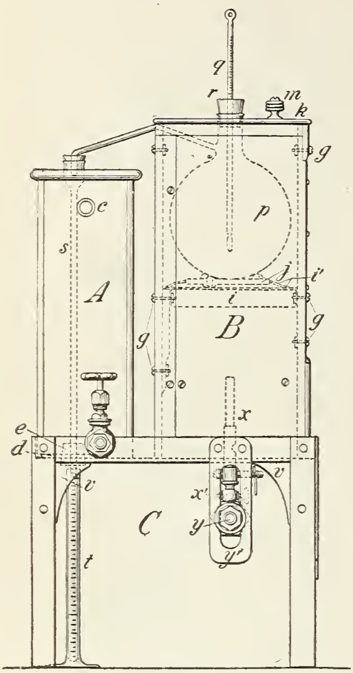

Fig. 5.—Plan of end of apparatus for moisture determination.

A, condenser; *B*, evaporating chamber; *C*, stand-supporting condenser and evaporating chamber, *c*, overflow pipe; *d*, washer soldered to bottom of condenser tank; *e*, rubber stopper supporting condenser tube; *g*, screw bolts; *i*, ledge for supporting gauze, triangle, and flask; *i'*, galvanized iron ring above gauze; *j*, flanged pipestem triangle; *k*, covers; *m*, handle on cover; *p*, distillation flask; *q*, thermometer; *r*, rubber stopper: *s*, condenser tube; *t*, graduated measuring cylinder; *v*, braces; *x*, burner; *x'*, extra stopcock beneath burner; *y*, gas pipe; *y'* support for gas pipe.

On the plate holding the gauze firmly in place (see fig. 4) rests a flanged pipestem triangle (*j*), which serves to raise the flask (*p*) about one-half inch above the brass-wire gauze, this being essential in order to prevent the corn which lies directly on the bottom of the flask from becoming too highly heated. If the flask rests on the gauze, the kernels in contact with the bottom of the flask directly over the flame will become carbonized and the percentage of water expelled will be too large. The interior arrangement of each compartment is more clearly shown in figure 9. The length of the flanged pipestem forming the sides of the triangle is 4 inches. The gauze is 30-mesh, made of No. 31 brass wire.

Each compartment is provided (see fig. 3) with an asbestos-lined cover (k) having a hole (l) in the center, thru which the neck of the

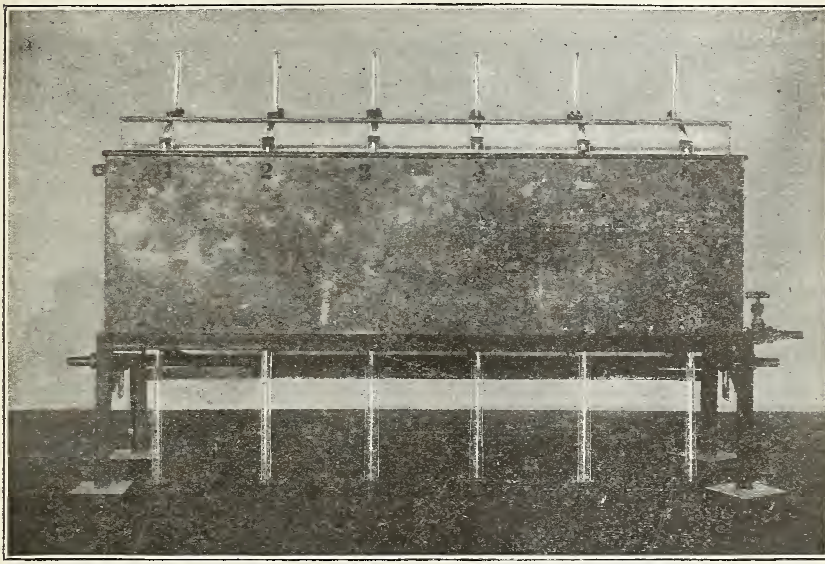

FIG. 6.—Front view of apparatus for moisture determination.

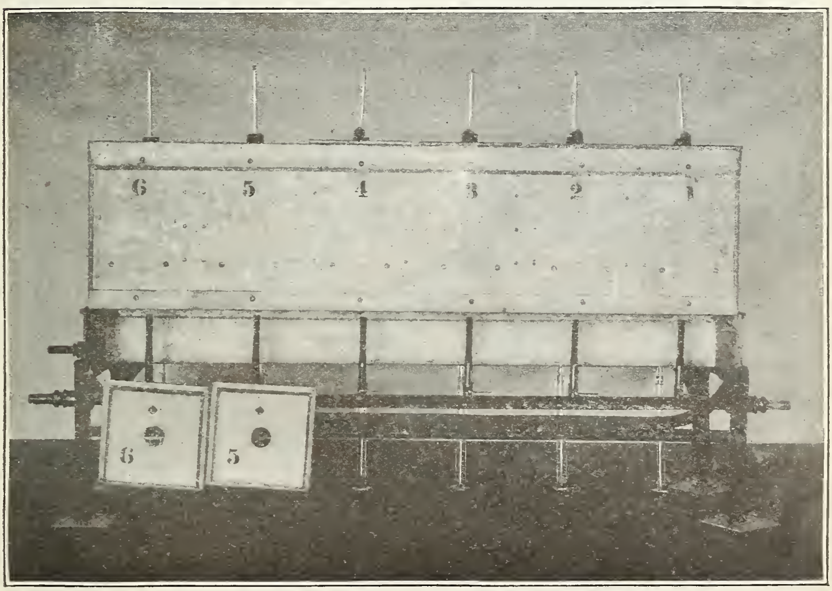

FIG. 7.—Back view of apparatus for moisture determination.

flask (p) projects. The hole in the galvanized iron is made about one-fourth inch larger than the hole in the asbestos lining, the latter having

a diameter of $1\frac{1}{4}$ inches, thus forming a one-eighth inch asbestos projection (l') to lessen the danger of breaking the necks of the flasks in placing or removing the covers. Each cover is provided with a wooden handle (m) and a five-eighths inch flange (n), the latter having a small notch at o, directly opposite the notch (o') in the side of the chamber. The asbestos in the notch (o') in the wall of the chamber should project sufficiently to form a cushion to protect the glass tube leading thru the notches o, o' to the condenser.

THE CONDENSER.

The condenser (figs. 3 and 5, A) consists of a plain copper tank 4 inches wide, 12 inches high, and of the same length as the evaporating chamber (B). In the bottom of the tank at points directly opposite the center of each of the compartments of the evaporating chamber are cut 1-inch holes for receiving the perforated rubber stoppers (e) thru which the ends of the glass condenser tubes (s) project into the measuring cylinders (t). Heavy one-eighth inch washers (d) are soldered around the holes in the bottom of the tank, so that the rubber stoppers (e) bearing the condenser tubes (s) can be prest in firmly, thereby avoiding the possible danger of any water leaking from the tank into the measuring cylinders. Thru the condenser tank passes a stream of cold water, entering thru the valve (a) and passing out at the overflow pipe (c). Connected with the valve (a) is a three-eighths inch pipe (b), which extends the full length of the tank. In this pipe, near each condenser tube, are two small holes (b'), drilled at such an angle that the cold water entering the tank will fall directly on the glass condenser tubes. In order to prevent the sides of the tank from bulging, extra braces (f) should be put in every 16 or 18 inches.

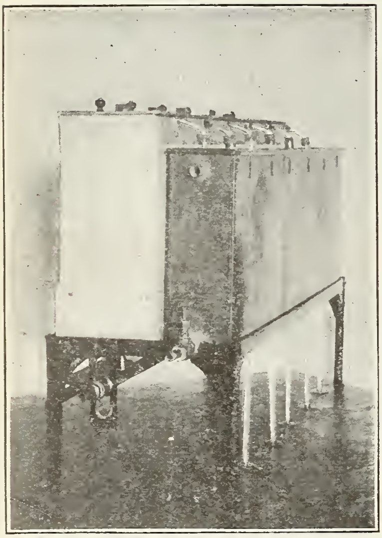

FIG. 8.—End view of apparatus for moisture determination.

THE STAND SUPPORTING THE EVAPORATING CHAMBER AND CONDENSER.

The stand (see figs. 3 and 5) supporting the condenser (A) and the evaporating chamber (B) is made of angle iron, with 1-inch sides and three thirty-seconds inch thick. The total height of the

stand is $9\frac{1}{4}$ inches, which raises the bottom of the condenser tank $8\frac{3}{8}$ inches above the work table. leaving ample room for the 8-inch measuring flasks (t) to be placed under the condenser tubes. The corners of the stand are strengthened by the braces (v). The cross piece (w) at the back of the stand is dropt 4 or 5 inches in order to facilitate the manipulation of the burners.

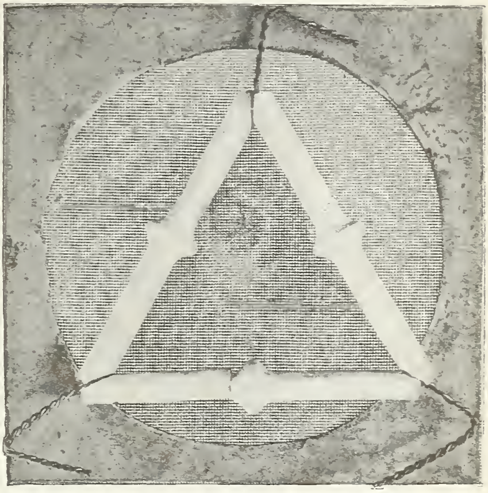

FIG. 9.—Interior arrangement of the compartments of the evaporating chamber, showing the position of the triangle over the gauze.

Between the burners (x) and the gas pipe (y) is inserted an extra stopcock (x'). With the extra stopcock directly beneath the burners the flow of gas can be regulated by setting either the valve in the burner (x) or the stopcock (x'), using the remaining one for turning on and off the gas. (Figs. 3 and 5.) The gas pipe (y) with the attached burners can be raised or lowered by loosening the nuts (z) at the slotted supports (y') at either end of the stand.

THE DISTILLATION FLASKS.

The flasks (figs. 4 and 5, p) in which the mixture of corn and oil is heated are primarily distillation flasks having short necks and specially constructed side tubes. (Fig. 10.)

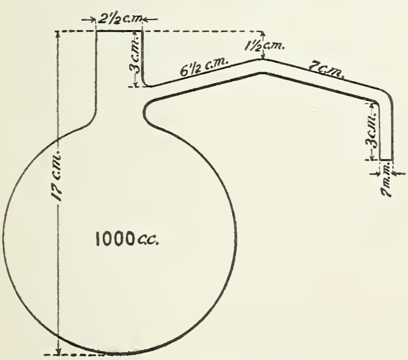

FIG. 10.—Distillation flask.

The flasks have a capacity of approximately 1,000 cubic centimeters. The necks of the flasks have a diameter of $2\frac{1}{2}$ centimeters and are made without a flange and sufficiently heavy to stand tight corking. The side tube, which is 7 or 8 millimeters in internal diameter, is inserted approximately 3 centimeters from the top of the neck. The respective lengths of the three arms of the side tube are $6\frac{1}{2}$, 7, and 3 centimeters. The bend between the two long arms is $1\frac{1}{2}$ centi-

meters below a horizontal line drawn from the top of the neck of the flask. The total height of the flasks should be 17 or $17\frac{1}{2}$ centimeters, or such that one-half centimeter or more of the neck will protrude thru the covers (k) of the evaporating chamber in order to protect the rubber stoppers (r) as much as possible from the action of the high temperatures.

THE THERMOMETERS.

While any standard chemical thermometer may be utilized, a thermometer graduated in degrees from 100° C. to 210° C. has been found most convenient. The 100-degree mark should come just at the top of the rubber stopper in the flask (17 centimeters from the bulb end of the thermometer), so that the rapidity of the rise in temperature can be watched if desirable after the water begins to pass over. The total length of such a thermometer need not be more than 27 or 28 centimeters. The bulb end of the thermometer should extend well into the mixture of corn and oil, approximately 1 centimeter from the bottom of the flask.

FIG. 11.—Condenser tube.

THE CONDENSER TUBES.

The construction of the condenser tubes (figs. 3 and 5), as represented at s in the detailed drawings, is shown in figure 11. The thimble at the top is 22 millimeters in diameter inside and 3 centimeters deep, giving ample space to make good connection with the distillation flasks by means of a rubber stopper on the end of the side tubes. The diameter of the remaining part of the tube is approximately 7 millimeters, the tube having a total length of 33 centimeters, so that the top of the tube will stand about one-half centimeter above the top of the water tank and the bottom of the tube project about 2 centimeters below the rubber stopper e at the bottom of the tank. The lower end of the tube should be cut at an angle, as shown in the illustration.

THE GRADUATED CYLINDERS FOR COLLECTING AND MEASURING THE WATER.

A convenient form of container for collecting and measuring the amount of water expelled from the grain is shown in figure 12. Each of the two cylinders here shown is 20 centimeters (approxi-

mately 8 inches) high and is graduated in fifths, the one with a reading capacity of 20 cubic centimeters and the other with a reading capacity of 25 cubic centimeters. For samples of very wet grain larger measuring cylinders will be necessary. With the graduations in fifths it is very easy to make the reading in tenths of a per cent, which is a sufficiently close percentage for all commercial grading of grain, as samples taken on different days will show a much wider variation. The graduations are in cubic centimeters, so that when 100 grams of grain are used for the test the percentage of water can be seen at once, 1 cubic centimeter of water representing 1 per cent. The cylinders should be of a uniform height, so that they can be used indiscriminately beneath any of the condenser tubes.

In expelling the water from the corn a small quantity of oil (less than one-half a cubic centimeter) is carried over into the graduated cylinders, which prevents them from drying rapidly after the readings have been made and the contents emptied at the close of the test. However, preparatory to their being used again the cylinders must be cleaned and dried, which can best be done with a test-tube cleaner having a small piece of sponge attached to the end.

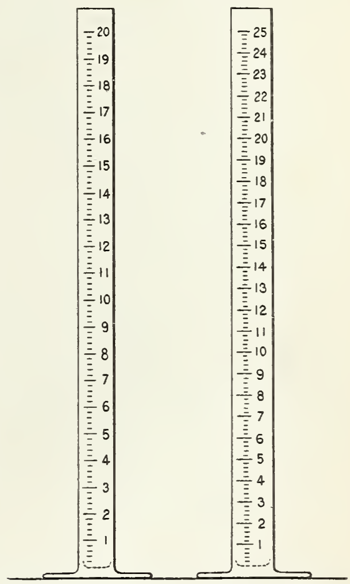

FIG. 12.—Graduated cylinders for measuring the water expelled from the grain.

COMPARISON OF RESULTS WITH DETERMINATIONS MADE IN A WATER OVEN.

The method and the apparatus for making moisture determinations of corn as described in the foregoing pages is so radically different from that commonly used in chemical laboratories that a comparison of results seems advisable.

Duplicate tests were made according to the rapid method and likewise in a water oven, the average percentage of moisture obtained in each case being shown in Table I.

TABLE I.—*Moisture in corn samples as determined by quick method and in water oven.*

Sample No.—	Moisture determined by quick method.	Moisture determined in water oven.	Sample No.—	Moisture determined by quick method.	Moisture determined in water oven.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
1	13.10	12.93	15	13.30	12.93
2	13.20	12.88	16	12.80	12.84
3	26.15	26.01	17	20.40	20.24
4	14.05	13.75	18	24.85	24.58
5	13.43	13.44	19	26.90	26.90
6	27.05	26.73	20	21.55	20.98
7	22.25	22.00	21	20.44	20.32
8	20.40	20.57	22	19.00	19.08
9	13.45	13.42	23	17.76	17.74
10	18.15	17.94	24	12.05	12.10
11	12.43	12.39	25	20.35	20.31
12	20.44	20.21	26	13.48	13.23
13	13.55	13.42	27	11.60	11.54
14	11.90	11.86	28	13.14	13.01

From the 28 samples represented in the foregoing table the average moisture obtained, according to the quick method, was 17.40 per cent and the average of the determinations made in a water oven was 17.26 per cent, a difference of 0.14 per cent. This difference is favorable to the quick method, for the percentage of moisture obtained by drying starchy grains in a water oven is slightly below the actual amount of free water in the grain.

In the majority of cases the whole kernels were likewise used for making the moisture tests in the water oven, the drying being continued from ninety-six to one hundred and twenty hours, and in the case of exceptionally hard kernels the drying was prolonged to one hundred and thirty-six hours or more.

The whole kernels were used in order to obviate the loss of water due to grinding, which in case of samples having a high percentage of moisture is considerable. One sample gave 26.01 per cent from the whole kernels and 24.36 per cent from the ground sample; another, 35.68 per cent from the whole kernels and 34.75 from the ground sample. The average of 16 samples gave 20.13 per cent for the whole kernels and 20.05 per cent for the ground sample, the moisture content of the different samples varying from 12.71 per cent to 35.68 per cent.

VARIATIONS IN DUPLICATE TESTS.

The amount of variation in different tests made at the same time from the same lot of corn will depend largely on the uniformity of the samples and on the care of the operator.

If the corn being analyzed is of inferior quality, containing a number of rotten kernels, or is a mixture of wet and dry corn, it is almost impossible to get samples of 100 grams each which will

give the same results, and in such cases a variation of one-half of 1 per cent or more is to be expected, whatever method is used for determining the percentage of moisture. But if the corn being examined is of uniform quality and the moisture determinations are carefully made, the variation in the results of duplicate tests will usually not exceed one-fifth of 1 per cent, while many samples will give a much smaller variation. However, a variation of even one-half of 1 per cent is sufficiently close for all commercial work, inasmuch as two samples taken on different days or from different parts of the same car or cargo will generally show a much greater variation than this.

Table II shows the results of the determinations of 15 samples of corn, representing almost all grades from new corn to wet and larvæ-eaten samples, in which the average variation is 0.22 per cent.

TABLE II.—*Variations in the percentage of moisture obtained from different tests made from the same lot of corn.*

Sample No.—	Moisture.						Average.	Variation.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	11.95	11.8	12.1	11.8	11.8	11.95	11.9	0.3
2	13.15	13.1	13.2	13.1	13	13.3	13.14	.3
3	11.4	11.75	11.7	11.4	11.75	11.7	11.6	.35
4	13.2	13.1	13	13.1	13	13.4	13.16	.4
5	17.7	17.6	17.7	17.5	17.9	....	17.68	.3
6	13.8	13.4	13.9	13.7	....	....	13.7	.5
7	20.4	20.3	20.7	20.3	....	....	20.4	.4
8	11.3	11.3	11.3	....	....	....	11.3	.0
9	20.7	20.9	....	....	....	....	20.8	.1
10	26.2	26.1	....	....	....	....	26.15	.1
11	13.2	13.2	....	....	....	....	13.2	.0
12	27	27.1	....	....	....	....	27.05	.1
13	24.8	24.9	....	....	....	....	24.85	.1
14	34.8	35	....	....	....	....	34.9	.2
15	35.9	36.05	....	....	....	....	35.98	.15

SUMMARY.

(1) The principal cause of the deterioration of corn in storage or during transit is an excessive amount of moisture.

(2) With the method and apparatus herein described for making moisture determinations, a percentage system of grading corn is well within the possibilities of the trade.

(3) The method described consists primarily in heating a definite quantity of corn in an oil bath to drive off the water, which is condensed and measured in a graduated cylinder.

(4) The time required for making the moisture determination will be from twenty to twenty-five minutes.

(5) With the proposed quick method for making moisture determinations one man familiar with laboratory work, with an assistant, should be able to test 200 samples in a day of eight hours.

(6) The apparatus consists primarily of (*a*) an evaporating chamber divided into two or more compartments, (*b*) a copper tank forming the condenser, and (*c*) a stand to support the evaporating chamber, the condenser, and the burners.

(7) The apparatus described shows six compartments, but it can be made in any size desired.

(8) The whole kernels are used for the test, no time being consumed by grinding; moreover, damp or wet grain can not be ground without a considerable loss of moisture.

(9) Only one weighing is required, for which an ordinary torsion balance is used, a delicate analytical balance being entirely unnecescessary.

(10) One hundred grams of corn are used for the test; consequently, each cubic centimeter of water in the graduated cylinder represents 1 per cent of moisture.

(11) When the thermometer in the distillation flask registers 190° C. (374° F.) the gas should be turned off, after which eight or ten minutes must elapse before the reading of the amount of water expelled is made.

(12) The distillation flask is closed and connected with the condenser tube by means of rubber stoppers of a grade that will not be readily affected by high temperatures.

(13) The oil used is a good grade of pure hydrocarbon oil having a flash point (in open cup) of from 200° C. to 205° C. Such oils are sold in the market as "engine oils" and can be purchased in barrel lots for 12½ or 15 cents a gallon.

(14) The oil should be poured into the flask first to lessen the danger of its being broken by the kernels of corn dropping on the bottom.

(15) The bulk samples from which the 100-gram samples are taken for the moisture test must be kept in air-tight containers if accurate results are expected.

(16) The bulk samples should be taken in such a was as to represent the quality of the entire lot of grain under consideration.

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